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TECHNICAL NOTE

Bureau of Land Management U.S. DEPARTMENT OF THE INTERIOR

EFFECTS OF FOREST FERTILIZATION ON WATER QUALITY IN TWO SMALL OREGON WATERSHEDS

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Introduction:

This study was initiated to determine the effect on the quality of streamflow by aerial fertilization of forested watersheds with urea. The Public Health Service has set a standard for nitrate ions (NC_3) plus nitrite ions (NO_2) in drinking water of 10 milligrams per liter. The objective of this study was to determine how much the concentration of nitrate and nitrite ions in streamflow would be increased following forest fertilization.

Several thousand acres of young growth Douglas-fir forest in western Oregon managed by the Bureau of Land Management were treated with a commercial nitrogen fertilizer in 1970 and 1971. This report deals with measurements of the effect of some of these forest fertilization projects on water quality. Water samples were taken from the streams of small basins within the fertilized areas and compared with water samples from adjoining basins of the same size, topography and forest cover located outside the fertilized area.

Water samples and other field data were collected by these personnel from the Salem District of the Bureau of Land Management: Pete Kirk, Gary Gebhardt, Jim Larrew, Cecil Fenney, and Pat Wallace. Water samples and supplementary data from the Eugene District were provided by: Karl Rymer, Bill Dingle, Alex Nagygyor, Glen Gard, Leonard Anderson, and Pete Kadaja.

Locations:

A 94-acre watershed, tributary to Nelson Creek (Sec. 11, T. 17 S., R. 8 W. about 27 miles west of Eugene) in the Siuslaw River basin, was selected for monitoring water quality from those areas fertilized in 1970. In 1971, Dollar Creek, an 85-acre watershed in the Mohawk River basin (Sec. 22, T. 15 S., R. 2 W. about 18 miles northwest of Eugene) was selected for monitoring water quality.

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Treatment:

The fertilizer was applied in the form of dry urea pellets (46% elemental nitrogen) by helicopter at a rate of 440 pounds per acre, giving approximately 200 pounds of nitrogen per acre. The Nelson Creek area was flown twice to aid in securing a uniform distribution of fertilizer; the Dollar Creek area was flown once. While no systematic sampling procedure was used to measure fertilizer distribution, observers walking the length of the watershed were satisfied that a reasonably uniform distribution was achieved. Buffer strips were not required although the pilots were to avoid making turns over water courses. The steep terrain and frequent occurrence of small stream channels required that flight lines generally cross the smaller channels.

Monitoring and Analysis of Water Samples:

The first water samples were collected a few days prior to fertilization in order to establish the quality of the streamflow before any treatment. Water samples were collected every few hours for the first several days after fertilization with increasingly longer intervals between samples as time progressed. The sampling schedule was changed slightly from 1970 to 1971 to better define the peak concentrations of the various chemical components following fertilization.

The samples were collected in plastic bottles, packed with ice in insulated boxes and shipped by bus to the State of Oregon Department of Environmental Quality Laboratory in Beaverton, Oregon. The samples were analyzed for urea, ammonia, nitrite and nitrate nitrogen under the direction of Dr. Loren Westgarth and Chemist Alan Hose.

In addition to the chemical analysis, stream temperatures and pH were measured. Stream discharge was estimated at the time each sample was taken and precipitation records were obtained from the nearest weather station.

Hydrology:

1970 - Nelson Creek.

Both the treated and adjoining untreated watershed have moderately steep topography and are frequently dissected by incised drainageways. At the time of fertilization, the flow from the treated area was about 0.2 cfs. By the end of June, 12 weeks after fertilization, the flow had dropped to about 0.1 cfs. and by the 15th week, flow was only inter-gravel. Appreciable streamflow did not resume until after the heavy rains of October 18-24, the 29th week after fertilization. Precipitation data were obtained from the U. S. Forest Service, Mapleton Ranger Station, which is about 12 miles WSW of the treated area.

1971 - Dollar Creek

A very heavy snowpack had melted off these paired watersheds only a few days before fertilization and the streamflow from the treated area was 2.1 cfs. at the time of fertilizer application. Streamflow had dropped to 0.8 cfs. by the fourth week (May 3), and after the fall rains the streamflow rate increased to 0.6 cfs. from the seasonal low flow rate of 0.11 cfs. on September 3. Precipitation data were obtained from a weather station at Holley about 10 miles NE of the treated area.

Results:

The values provided by the DEQ laboratory analysis together with the streamflow rates are shown in Tables 1 and 2. The effect of forest fertilization for each of the chemical components is considered to be the value for the treated area minus the value for the untreated area. For those instances where the value for the untreated area is greater than that of the treated area, the effect is considered to be zero. This convention was used in developing the concentration graphs for the 1970 data (Figures 1 and 2) and the 1971 data (Figures 3 and 4). Weekly precipitation is also shown on the concentration graphs.

The major points developed from this monitoring program are:

1. The background nitrogen content of the untreated streams were:

   a. Urea (N) - usually less than 0.02 ppm.

   b. Ammonia (N) - varied from less than 0.01 ppm. to 0.35 ppm.

   c. Nitrite (N) - always 0.01 ppm. or less.

   d. Nitrate (N) - ranged from less than 0.02 ppm. to 4.3 ppm. This value of 4.3 ppm. from the Nelson Creek area for October 23, 1970, seems suspiciously high although there is little published data for comparison. The average background value for Nelson Creek was 0.29 ppm. (excluding the peak of 4.3) and that of Dollar Creek was 0.06 ppm.

2. The peak urea (N) recorded in the Nelson Creek area was 8.6 ppm. as compared to 44.4 ppm. for the Dollar Creek area. These peaks were probably caused by fertilizer which was deposited in the stream channels and on saturated soils adjacent to the streams. These peaks are short-lived and within 3 to 4 days the urea content had dropped back to pre-treatment levels.

3. The greatest difference in the level of ammonia (N) between the treated and untreated areas for both years was about 0.43 ppm.

TABLE 1. BLM FERTILIZATION STUDY - NELSON CREEK
Date of Application: April 4, 1970, Beginning at 0600

Date	Treated Area (T)				Untreated Area (U)				
	PPM				PPM				
	Urea	NH_3	NO_2	NO_3	Urea	NH_3	NO_2	NO_3	Streamflow (cfs)
3/12/70		0.02	0.01	0.13		0.01	0.01	0.22	(T)0.19
4/3/70	0.02	0.24	0.01	0.29	0.02	0.35	0.01	0.41	(U)0.08
4/4/70									
0800	0.02	0.30	0.01	0.84	0.02	0.33	0.01	1.3	(T)0.19
1500	8.6	0.24	0.01	0.12					
4/5/70									
0100	4.5	0.29	0.01	0.17					
1300	2.1	0.32	0.01	0.21					
4/6/70									
1300	0.9	0.27	0.01	1.5	0.20	0.22	0.01	0.15	(T)0.19
4/8/70									
0955	0.02	0.14	0.01	2.1					(T)0.17
4/12/70	0.03	0.07	0.01	1.4	0.02	0.01	0.01	0.29	(T)0.23
									(U)0.08
4/18/70	0.01	0.01	0.01	1.5	0.02	0.01	0.01	0.17	(T)0.21
									(U)0.07
5/2/70	0.02	0.01	0.01	0.58	0.02	0.01	0.01	0.16	(T)0.35
									(U)0.19
5/23/70	0.02	0.06	0.01	0.34	0.02	0.05	0.01	0.15	(T)0.07
									(T)0.19
6/4/70	0.02	0.01	0.01	0.25	0.02	0.01	0.01	0.16	(T)0.10
									(U)0.03
6/15/70	0.02	0.05	0.01	0.40	0.02	0.04	0.01	0.14	(T)0.09
									(U)0.03
7/20/70	0.02	0.02	0.01	0.30					
10/23/70	0.02	0.01	----	7.6	0.02	0.02	----	4.3	(T)0.21
									(U)0.10
12/14/70	0.02	0.05	----	0.52	0.02	0.01	----	0.22	(T)1.02
									(U)0.33

NO_3 Mean Background Level = .29 PPM (Excluding the peak value of 4.3 PPM)

TABLE 2. BLM FERTILIZATION STUDY - DOLLAR CREEK
Date of Application: April 3, 1971, Beginning at 10:30

Date	Treated Area (T)				Untreated Area (U)				
	PPM				PPM				
	Urea	NH_3	NO_2	NO_3	Urea	NH_3	NO_2	NO_3	Streamflow (cfs)
4/1/71									
1000					0.28	0.04	(0.01	(0.02	
1830	0.21	0.03	0.01	(0.02					
4/3/71									
1200	44.4	0.49	(0.01	(0.02					(T)=1.46
									(T)=2.10
1400	18.0	0.31	(0.01	0.02					
1800	9.6	0.34	(0.01	0.03					
2200	4.6	0.23	(0.01	0.03					
4/4/71									
600	1.78	0.20	(0.01	0.04					
1000	0.68	0.16	(0.01	0.06					
4/7/71									
1000	1.08	0.22	(0.01	0.08					
1030					(0.02	0.03	(0.01	0.02	
4/9/71									
0915	0.20	0.31		0.13					2.11
4/13/71									
1045					(0.02	0.08		(0.05	3.66
1200	0.04	0.11		0.08					3.23
4/19/71									
1345	(0.02	0.08		0.07					1.66
1500					(0.02	0.09		(0.05	1.66
5/3/71	(0.02	0.08		(0.05	(0.02	0.08		(0.05	(U)0.74
									(T)0.83
6/10/71	(0.02	0.03		0.05	(0.02	0.03		(0.05	(U)0.49
									(T)0.41
6/18/71	(0.02	0.07		0.04	0.04	0.10		0.04	(U) .21
									(T) .21
8/03/71	(0.02	0.02		0.04	(0.02	0.13		0.08	(T)0.466
									(U)0.26
9/3/71	(0.02	0.11		0.11	(0.02	0.01		0.18	(U)0.113
									(T)0.21
10/1/71	0.01	(0.01		0.08	(0.02	0.02		0.13	(U)0.32
									(T)0.59

NO_3 Mean Background Level = .06 PPM

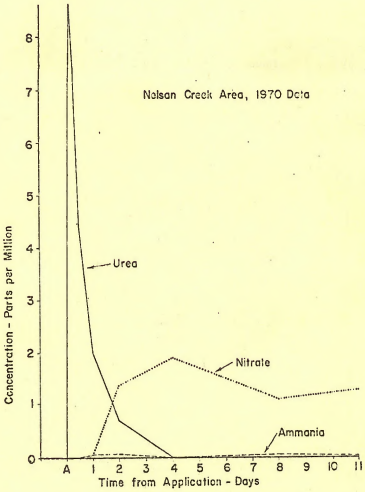

Figure 1 - Immediate Effect of Fertilization on Water Quality, 1970. Post-treatment values minus background values.

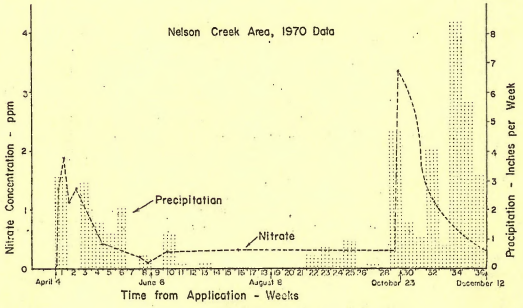

Figure 2 - Trend of Nitrate Concentration in Streamflow, 1970 Data. Post-treatment values minus background values.

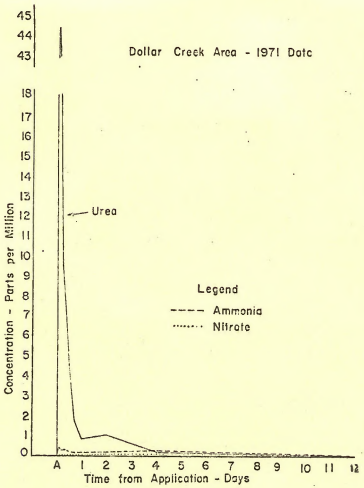

Figure 3 - Immediate Effect of Fertilization on Water Quality, 1971. Post-treatment values minus background values.

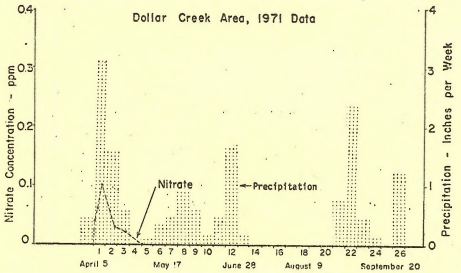

Figure 4 - Trend of Nitrate Concentration, 1971 Data. Post-treatment values minus background values.

4. Nitrite nitrogen did not appear in quantities large enough for measurement by the analysis methods used.

5. The pattern of nitrate (N) was quite different for the two years data. The Nelson Creek area showed a peak value of 1.8 ppm. above the untreated level four days after fertilization. The nitrate content of the streamflow dropped rapidly for about 30 days and then more slowly for the next 30 days at which time it was comparable to pre-treatment levels. A second peak of 3.3 ppm. was measured after the onset of the fall rains. Seven weeks later this peak had decreased to 0.30 ppm. above the untreated level. By contrast, the nitrate content of streamflow from the Dollar Creek area showed very little increase over that of the untreated watershed. Furthermore, there was no elevation of nitrate content above the level of the untreated watershed after the fall rains began.

6. The variation in the amounts and timing of nitrogenous material leaving the two treated streams is a good indication that the two watersheds have distinctly different systems. Soils, vegetation, stream gradient and antecedent soil moisture may all affect the results. As noted in the section on Hydrology (page 2) the fertilizer was applied to the Dollar Creek area immediately following the melt of a very heavy snowpack. The higher flow from the Dollar Creek watersheds at the time of application indicates an expended channel system and an enlarged wetter streamside zone. This may account in part for the higher yield of Urea (N) as compared to the Nelson Creek project. A heavy stand of alder along the stream in the treated watershed on the Nelson Creek project might account for the higher background values for nitrate as well as the flush of nitrate (N) following the fall rains.

7. No significant changes in pH were observed between the treated and untreated areas.

Conclusions and Recommendations:

There is no level set specifically for nitrogen under Oregon Water Quality standards, but the U. S. Public Service has recommended a maximum permissible level of 10 ppm. for the sum of nitrate nitrogen plus nitrite nitrogen in public water with a "desirable criteria of virtually absent." The results of these two studies show that this maximum was not seriously approached. The peak of urea content in 1971 and the peak nitrate content in the fall of 1970 are apparently very short-lived and would not constitute a hazard to drinking water supplies. However, it is possible that the sampling schedule, while indicating a pattern or trend, did not sample other peaks that may have occurred.

Based on a rough approximation of streamflow and the excess of nitrogen over the background values, it is estimated that the equivalent of less than one percent of the fertilizer applied left the watershed through streamflow. When considering the relatively short time that the fertilizer nitrogen was present in the stream and the levels reached, it appears that the fertilization of a small forested watershed does not constitute a hazard to the commercial forest environment. Our concern for the environment and any effect on downstream users is such that at least three precautions should be observed at this time:

1. Work to avoid application of fertilizer directly to streams or saturated soil immediately adjacent to stream channels. This will reduce the risk of large concentrations of urea (N) leaving the fertilized areas by streamflow.

2. Special care should be taken to select areas for fertilization far enough upstream from municipal and other drinking water supplies so that streamflow will be diluted by other tributaries before reaching water intake facilities. This will assure that any high levels of nitrogen in the streamflow from fertilized areas as a result of faulty application or wind drift will be reduced to safe levels before entering a water supply.

3. Avoid selecting large areas for forest fertilization upstream from small impoundments where nitrate accumulation might be detrimental if it occurred. If streamflow from a large area selected for forest fertilization will flow directly into a small impoundment with little or no dilution, then the selected area may need to be subdivided into smaller units for fertilization in successive years. The appropriate State agencies should be contacted for help in evaluating those conditions in the impoundment which may be adversely affected by a possible nitrate accumulation.